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Space and Consequences: The Impact of Different Formal Learning Spaces on Instructor and Student Behavior

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This article presents the results of a quasi-experimental research project investigating the impact of two different formal learning spaces – a traditional classroom and a technologically enhanced active learning classroom – on instructor behavior, classroom activities, and levels of on-task student behavior at the University of Minnesota. Using time-series data collected as part of a series of classroom observations, we demonstrate that not only are clear differences manifest in terms of what occurred within each space, but that the different classroom types are linked causally to the observed differences in instructor and student behavior.

Introduction

Interest in building, teaching in, and researching the impact of technologically enhanced learning spaces appears to have grown exponentially in the last decade with EDUCAUSE, the leading organization responsible for promoting the application of new technologies in educational settings, leading the charge. Its numerous publications advocating for the creation of new classroom spaces that are conducive to the sound pedagogical use of educational technologies has prompted colleges and universities to initiate any number of construction projects to bring these innovative classrooms to their campuses. As the new classrooms have proliferated, large cadres of instructors have enthusiastically embraced them, leaving behind the traditional classroom and shifting pedagogical approaches so as to take advantage of the **features** of these new spaces. Indeed, once built, they have come. Unfortunately, but not surprisingly, research assessing the efficacy of these new classroom spaces has lagged behind considerably, with very few empirical studies offering evidence of their impact on educational outcomes. Although the evidence to date is sparse, the study of learning spaces is beginning to garner considerable and serious attention by respected researchers globally.

Building upon previous quasi-experimental research conducted at the University of Minnesota that found that flexible, technologically enhanced classroom spaces improved student learning (as measured by course grades) more than taking the same course in a traditional classroom setting (Whiteside, Brooks, & Walker, 2010; Brooks, 2011; Walker, Brooks, & Baepler, 2011), the research presented here goes beyond the established evidence that learning spaces, in fact, *do* matter and begins the process of explaining how learning spaces matter.

Drawing upon class observational data collected for two sections of a single course taught by the same instructor with one section meeting in a traditional space and the other convening in an enhanced classroom, we demonstrate that the instructor and students enrolled in this course behaved differently and engaged in classroom activities differently depending upon the type of classroom in which they took the course. Furthermore, by taking advantage of the temporal nature of these data, we are able to model the causal impact of formal spaces on levels of on-task student behavior as a function of instructor behavior and classroom activities with respect to both classroom types featured in the study.

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Literature Review

The recent enthusiasm for shifting the manner in which institutions of higher education approach and conceptualize classroom space has been fueled by a host of articles extolling the potential transformative power of formal learning spaces on teaching practices and learning outcomes. The case for space has been made from a variety of approaches, each of which is shaped by the particular perspective of the interested parties. Designers and technologists tend to focus on the architectural characteristics of different spaces, showcasing particular innovations related to student and instructor based technologies and/or furniture configurations that may enhance the teaching and learning experiences that occur within them (Oblinger, 2006; Lippincott, 2009; Long & Holeton, 2009). Those more engaged in the scholarship of teaching and learning highlight the importance of pedagogical approaches and issues related to teaching in new learning environments via case studies that highlight lesson learned, best practices, potential pitfalls, and other practical considerations (Montgomery, 2008; Jorn, Whiteside, & Duin, 2009; Jankowska & Atlay, 2008). Additionally, theoreticians offer normative and philosophical treatments of the significance of learning spaces to the processes of teaching and learning and considerations of what these new spaces portend for the future of higher education (Savin-Baden, 2008; Thomas, 2010; Summerfield & Smith, 2011). Despite the richness and breadth of these treatments of the subject, most of these are bereft of empirical evidence that demonstrates what, if any, measurable impact formal learning spaces have on educational processes and outcomes. And while advocates for technology-enhanced, flexible classroom spaces increasingly have called for research studies that tease out the relationship between physical space, approaches to teaching, and learning outcomes (Savin-Baden, McFarland & Savin-Baden, 2008; Temple, 2008; and Hunley & Schaller, 2009), the tendency has been to report on measures of satisfaction with newly designed spaces, qualitative feedback on student and instructor experiences, and other evaluative metrics (Jankowska & Atlay, 2008; Soderdahl, 2011; Matthews, Andrews, and Adams, 2011).

Although the preponderance of literature on learning spaces thus far contributes little in the way of empirical testing of the impact of space on teaching and learning, researchers from learning space pioneers Massachusetts Institute of Technology (MIT) and North Carolina State University are responsible for two early and important exceptions. MIT researchers who assessed their Technology Enabled Active Learning (TEAL) project found that the deployment of an active learning curriculum in redesigned spaces performed better than lecturing techniques in a traditional classroom in terms of reducing failure rates and increasing conceptual understanding (Dori et al, 2003). Similarly, researchers from North Carolina State also found that the classrooms and curriculum associated with their Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP) reduced failure rates and contributed to conceptual understanding while improving class attendance, student attitudes, and problem-solving skills (Beichner et al., 2007; Gaffney et al., 2009). Although both of these projects were able to demonstrate that the combination of newly designed learning spaces and active learning approaches to teaching contributed to improved student learning outcomes, the research designs on which they were based did not provide enough in the way of experimental controls so as to isolate the relative effects of either space or pedagogy.

Building upon the SCALE-UP and TEAL research projects, a team of researchers from the University of Minnesota partnered with three faculty members who were teaching courses in the Active Learning Classrooms (ALCs)[1] to collect data to evaluate empirically the extent to which formal learning environments affect teaching and learning practices beginning in fall 2008. Numerous data collection methods, such as faculty interviews, class observations, course assignment logs, photo surveys, student surveys, and focus groups, were employed in order to evaluate systematically a number of testable hypotheses in service to the larger research question.

For one of the courses, an introductory biology course, the author seized the opportunity to employ a quasi-experimental design from which robust comparative findings could be derived. Two sections of the course were offered by the same instructor, who is an award-winning, veteran teacher, with one section taught in a traditional classroom that has a whiteboard, projection screen, and instructor podium at the front of the room, and rows of seats and tables facing forward (see Figures 1 and 2) and another taught in an ALC (see Figures 3 and 4).

Figure 1. The Traditional Classroom.

[1] The University of Minnesota's ALCs are flexible, student-centered, active learning spaces that contain large, round tables that seat nine students that can be broken out into teams of three for group-based work and feature switchable laptop plug-ins that afford the opportunity for student work to be pushed either to a dedicated wall-mounted, flat-screen monitor or large classroom projection screen at the discretion of the instructor from a centralized control panel. Additionally, ALCs have marker-boards mounted to the walls around the perimeter of the room so that students have ready access to a working surface, microphones at each table, and wide aisles between and around each table for ease of access to any point in the room. For additional information on ALCs, including photos and videos, see the Office of Classroom Management's dedicated site: (http://www.classroom.umn.edu/projects/alc.html).

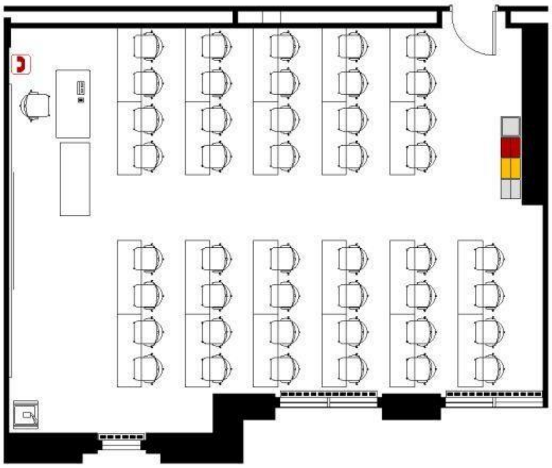

Figure 2. A Schematic Diagram of the Traditional Classroom

Figure 3. The Active Learning Classroom.

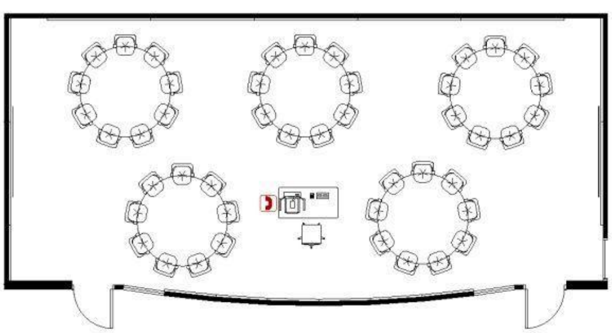

Figure 4. A Schematic Diagram of the ALC.

Excepting the non-random assignment of students to sections of the course, this arrangement allowed researchers to control for numerous potentially confounding factors thereby isolating the relative impact of the ALC environment on teaching and learning.

In terms of controls, both sections of the course were offered during an 8:15-9:55 a.m. time slot with the traditional section meeting on a Monday/Wednesday schedule and the ALC section meeting on a Tuesday/Thursday rotation. The instructor used the same course materials, assignments, schedules, and exams for both sections and made considerable efforts to keep his approach to course delivery the same in each section. Although the randomization component required to make the design fully experimental was absent from the study as students were automatically enrolled into their lecture sections based on the laboratory for which they registered, the only demographic characteristic of students that varied significantly across the sections was the composite ACT score.

The only factor that was allowed to vary systematically across the sections was the type of formal learning space in which the course was being taught. With the quasi-experimental controls inherent to the design of this portion of the project, we found that the ALC had an independent and significantly positive effect on student learning as measured by grades. Students in the ALC, who had on average significantly lower ACT scores, overcame the predicted achievement gap to earn statistically the same average grade as their peers in the traditional classroom setting. Additionally, we found that while the ALC had significant and positive effects on student learning, it did so without undermining the reliability of ACT scores to predict student grades within introductory year courses; that is, high ACT scores continued to predict higher grades and low ACT scores continued to predict lower grades (Brooks, 2011).

Although the finding that the room exerted an independent and significantly positive effect on student learning is an important result that confirms many of the assumptions made about transforming learning spaces, the mechanisms by which this outcome was achieved remain largely unknown and under-researched. That is, we know very little about how ALCs affect the actual instructors and students working within them. We should also be suspicious of over-simplified interpretations of these results that might attribute agency to what is really an inert physical space, thereby suggesting that the space directly caused increased levels of learning. Instead, we should focus our attention on how the formal classroom spaces serve as indirect causal agents that affect the actors within them and how what is facilitated or constrained within those spaces elicit outcomes conducive to the previously observed gains.

One theoretical assumption about how this process takes places posits, "space exerts situation-related influences on human activities and experiences as they are enacted and felt in environmental settings" (Amedeo, Golledge & Stimson, 2009, p. 13). For these authors, two primary sets of variables associated with the physical space provide the relative contextual differences between any given sets of spaces: structure and scale. Structures are represented by the basic physical arrangements, configurations, and connectedness; scaling is related to the size and expanse of physical space. Given that scaling and structuring are inherent to any physical space and prior to and, therefore, independent of factors that are introduced to them, the theory suggests that different spaces should produce different effects, even if one attempts to perform the same task within their confines. In order to isolate the independent influence of space, both the space and the actors need to be observed systematically. Having collected observational data on each of the courses in the original study, we are able to systematically and formally test these assumptions regarding the effect of space on its actors. It is to that task we now turn our attention.

Data and Methods

We designed a customized classroom observation instrument with the assumption in mind that in order to isolate the effects of space on participant behavior we needed to treat instructor and student behavior as conceptually linked to the formal learning spaces in which the course was convened. The instrument (available at http://z.umn.edu/cof) was used to collect data on 32 variables related to classroom activities (e.g. lecture, group activities, class discussion, Q&A, presentations, etc.)[2], the mode of content delivery, instructor behavior (e.g. consulting with students and physical location), levels of on-task student behavior, environmental conditions in the room (e.g. temperature, noise levels, lighting, etc.), and narrative descriptions of events. The course observation data was collected from randomly selected, unannounced class periods in 13 of 28 (46.4%) of the meetings of the traditional classroom section and 14 of 28 (50.0%) of the instances of the ALC section.

Data were recorded for each variable in five-minute intervals producing 208 observational intervals for the section meeting in the traditional classroom and 224 observational intervals for the ALC section. Given the duration of the coding intervals, it was not uncommon for multiple activities, modes of deliverance, instructor and student behavior, and environmental conditions to be recorded a single interval. Thus, for example, it would be possible for an instructor to lead a discussion and conduct a group activity or for students to engage in both high and low levels of on-task behavior in the same interval. Researchers observed class periods from different locations in the respective classrooms in order to reduce coding bias and to increase variability in perspective. Inter-coder reliability tests revealed a remarkably high level of agreement among the five individuals responsible for collecting the course observation data (Cronbach's $\alpha = .93$).

To examine the impact of differences of physical spaces on what transpires in the classroom, we focus our attention on four groups of variables: classroom activities, content delivery modes, instructor behavior, and student behavior. Classroom activities include instructor-based lecture, assigned group activities, class discussion between and among students, and question and answer (Q & A) between the instructor and students. In this study, course content delivery entailed primarily PowerPoint slides and use of marker-boards by students and/or the instructor. In terms of instructor behavior, the variables include instructor location in the room (at the podium/desk and not at the podium/desk) and interaction with students (consulting with an individual or discrete group of students and not consulting with an individual or discrete group of students). For student behavior we include three levels of student on-task behavior: 0-20% on-task, 21-80% on-task, and 81-100% on-task (Lawrenz, 2004). All variables are coded dichotomously (variable present = 1; variable absent = 0). Items for which there is no variation (e.g. mean = 0; standard deviation = 0) in either section are excluded from our analysis.

Analysis

Our analysis of the impact of formal learning spaces on classroom activities, modes of content delivery, and instructor and student behaviors begins with a comparison of observational variables by room type. To test formally these relationships, we advance the null hypotheses that

[2] Lecture is defined as the unidirectional dissemination of content from the instructor to students. Group activities are those activities where two or more students engage in an activity assigned by the instructor. Class discussion is a multidirectional and free-flowing conversion that moves freely from instructor to student, student to instructor, and/or student to student. Question and answer is identified as moments where either the instructor poses a question to students or a student poses a question to the instructor. Presentations are the unidirectional dissemination of content from a student to the instructor and other students.

there are no statistically significant differences between room-type for each variable under consideration.

Classroom Activities

For classroom activities, we reject the null hypothesis of there being no significant difference between classroom types for two of the four classroom activities for which we have data (see Table 1). Lecture activities occurred in 77.4% of the observational intervals in the traditional classroom setting and only 54.5% of the intervals in the ALC, a difference of 22.9% that is significant at the $p < .0001$ level. Also highly significant is the finding that class discussions occurred in 48.0% more of the observational intervals in the ALC than in the traditional classroom ($p < .0001$). Conversely, we fail to reject the null hypothesis for the remaining two classroom activities: group activities and question and answer sessions.

Table 1. Difference of Means Tests of Classroom Activities and Content Delivery Modes: Traditional Classroom versus Active Learning Classroom

	Traditional Classroom	Active Learning Classroom	*t*	*df*
Classroom Activity				
Lecture	0.774 (0.419)	0.545 (0.499)	4.786**	386
Group activity	0.366 (0.483)	0.455 (0.499)	1.769	386
Discussion	0.024 (0.155)	0.504 (0.501)	11.858**	386
Q & A	0.409 (0.493)	0.451 (0.499)	0.830	386
Content Delivery Mode				
PowerPoint	0.865 (0.343)	0.790 (0.408)	1.904	385
Board	0.368 (0.484)	0.469 (0.500)	1.982*	385
Instructor				
At podium	0.951 (0.216)	0.692 (0.463)	6.662***	386
Not at podium	0.311 (0.464)	0.893 (0.310)	14.790***	386
Consulting	0.274 (0.448)	0.549 (0.861)	3.731**	386
Not Consulting	0.774 (0.419)	0.861 (0.347)	2.220*	385
Students				
High on task	0.933 (0.251)	0.772 (0.420)	4.357***	386
Mixed on task	0.341 (0.476)	0.250 (0.434)	1.969*	386
Low on task	0.030 (0.172)	0.036 (0.186)	0.282	386

NOTE: $^{*}p < .05$; $^{**}p < .001$; $^{***}p < .0001$. Cell entries are means with standard deviations in parentheses.

Table 1. Difference of Means Space and Consequences.

Given that the instructor designed PsTL 1131 with a group-based, problem-solving pedagogy in mind, the lack of difference between sections in the levels of group activity is not surprising. Nor would one necessarily expect the ability of the students and instructor to ask and answer questions of one another to be enhanced or impeded by the differences in these formal learning environments. However, despite the best efforts of the instructor to teach each section of the course in an identical manner and to lecture minimally, the traditional classroom, which is designed for the more traditional pedagogy of delivering information via lecture, elicited that activity at significantly higher levels than the more de-centered space designed to accommodate more flexible pedagogies. When combined with the layout and design of the traditional classroom, class discussion in that space dropped to incredibly low levels. By comparison, the round tables and flexible layout of the ALC appear to be highly conducive to student-student and student-instructor interactions.

Content Delivery Modes

The instructor employed two basic content delivery modes throughout the duration of the course: PowerPoint slides and classroom marker boards. While other modes were occasionally used to share information with students, their infrequency undermines our ability to test for differences between their uses across the classroom types. For the PowerPoint slide delivery mode, we fail to reject the null hypothesis of no difference between traditional classroom (86.5%) and the ALC (79.0%). However, we do reject the null hypothesis for the use of marker-boards by students and/or the instructor. In the ALC, the glass marker-boards were used 10.1% more frequently than in the traditional counterpart, a difference that is significant at the $p < .05$ level.

Regarding content delivery, the lack of difference between sections for the use of PowerPoint slides is not surprising given that it was selected a priori by the instructor as the vehicle by which the information necessary to set up group-based problem-solving activities was to be conveyed. The difference in use of marker-boards is explained, however, both by the location and number of boards present. In the traditional classroom, the only boards available for use were at the front of the classroom to which only the instructor had easy access; in the ALC, marker-boards cover every wall in the room and are accessible readily both to the instructor and the students, who are free to and encouraged to use them as needed for in-class work.

Instructor Behavior

We reject the null hypothesis of no difference in instructor behavior between the classroom types for all four variables in this category. In the traditional classroom, the instructor was at the podium in the front of the room in 95.1% of the observational intervals; in the ALC, he was at the centrally located podium only 69.2% of the time, a difference of approximately 26% that is significant at the

$p < .0001$ level. Conversely, the instructor was not at the podium (e.g. he was elsewhere in the room) in the ALC 89.3% of all recorded intervals compared to only 31.1% of the time in the traditional setting, a difference is also highly significant ($p < .0001$). The instructor also consulted privately with individual or small groups of students more of the time in the ALC (54.9%) than in the traditional classroom (27.4%), a difference that is significant at the .0001 level. Finally, the instructor was engaged in activities other than consulting only 8.7% less in the traditional classroom, a difference that is minimally significant at the 0.05 level.

The physical constraints and opportunities offered by each type of space had the most consistent and obvious influences on instructor behavior. The traditional classroom with its narrow center-aisle and forward-facing tables and chairs appears to have severely limited the mobility of the instructor, who was recorded as being at the podium in nearly every observational interval and who rarely left that area for other parts of the room. Similarly, the tight and linear distribution of tables and chairs appears to have limited the ability of and opportunity for the instructor to consult privately with individual or small groups of students. Conversely, the instructor was at the podium considerably less time and not at the podium more frequently in the ALC where the spaces and pathways between tables are wider, numerous, and more non-linear. The lack of congestion of classroom furniture is also associated with more frequent consults with students during the classroom periods.

Student behavior

In terms of levels of student on-task behavior, we fail to reject the null hypothesis of no difference between sections for the lowest level of on-task behavior in which less than 20% of students appeared to be engaged with the assigned activity in a given interval. However, we reject the null for both the remaining categories. Students in the traditional classroom were observed to be on-task 9.1% more frequently at mixed levels than their peers in the ALC at than their peers in the ALC, a difference that is modestly significant at the .05 level. Furthermore, students in the traditional classroom were recorded to be on-task at the highest levels (greater than 80%) in 93.3% of the observed intervals compared to ALC students who exhibited high levels of on-task behavior in only 77.2% of the time, a difference of 16.1% ($p < .0001$).

While the physical differences in the classrooms are associated significantly with differences in student levels of on-task behavior, these differences do not appear to occur in the manner expected. That students in the traditional classroom were observed to be significantly more frequently and consistently engaged with classroom tasks than students in the ALC runs counter to evidence regarding students' attention spans in traditional environments and to the spirit and intent of the ALC, a space designed to promote engagement via flexible pedagogical approaches. One possible explanation is that students were, in fact, more engaged in the traditional classroom. Yet, if on-task behavior is associated positively with performance, this seems unlikely given that students in the ALC outperformed their peers in the traditional classroom (Whiteside, Brooks, & Walker, 2010; Brooks, 2011; Walker, Brooks, & Baepler, 2011). Alternatively, there may be issues related to the manner in which the data was coded. But given the high level of agreement in our tests of inter-rater reliability and a lack of significant coding differences between individual researchers' data for the section meeting in the traditional classroom, this seems highly unlikely.

Instead, there is a distinct possibility that the issue lies with the operationalization and measurement of on-task behavior. While researchers were coding on-task behavior consistently, the very definition by which we catalogued them may not be appropriately specified given that they were derived from a model of on-task behavior familiar to traditional classroom settings. The visible cues used by researchers to code levels of on-task classroom behavior included such things as facing the instructor, marker-board, or projector screen, taking notes, participating in group activities or discussions; conversely, off-task behavior included participation in private, aside conversations, using computers, cell phones, smart phones, or other technologies for seemingly non-class related activities, sleeping, or otherwise disruptive behavior. These cues of on-task behavior are largely the product of our expectations of how students should behave and work very well in a traditional setting. Thus, our measurement of on-task behavior may be somewhat misspecified in that the behavior of students in a traditional classroom is de facto engaged behavior with the result of overstating the on-task behavior in the traditional section while understating it in the ALC, where some of the apparently off-task behaviors very well may have been on-task.

Formal Learning Spaces, Classroom Activities, and Actor Behavior

Our difference of means tests on the four categories of observational variables provide evidence that differences in classroom activities, instructor and student behavior, and content delivery are manifest in different types of formal learning spaces despite the quasi-experimental controls inherent to the research design. The instructor lectured more and was at the podium more in the traditional space; students appeared to be on-task at higher and mixed levels in the traditional classroom. Conversely, classroom discussion and use of the board occurred more frequently in the ALC while the instructor moved about the room and consulted with students more in the ALC space. The instructor also did not consult with students significantly more in the ALC than in the traditional classroom. The breaks along these lines suggest that particular activities and behaviors might not only be correlated with particular spaces, but that the observational variables may be correlated with one another in complex and interesting ways. For example, it is plausible that if the instructor is lecturing, he might tend to hover near the podium, leading discussion less frequently, and consulting less. Similarly, consulting discretely with students probably requires the instructor to be away from the podium, precludes lecturing, and occurs when students are busy with group activities.

To explore the relationships that exist between the formal learning spaces and what transpires in them, we formally test the null hypotheses that no significant dyadic correlations exist between the instructor behavioral and classroom activity variables. Table 2 presents the pairwise tetrachoric correlation coefficients (rho) for each of the dichotomous variables of interest related to instructor behavior, classroom activities, and room type. We reject the null hypothesis of no correlation for all but five of the dyadic relationships (ALC and group activity; discussion and lecture; discussion and group activity; not consulting and group activity; not consulting and discussion) with the majority of variable pairs correlated at highly significant levels.

Table 2. Pairwise Tetrachoric Correlations: Room Type, Activities, and Instructor Behavior

	ALC	Lecture	Group Activity	Discussion	Podium	Consulting	Not at Podium	Not Consulting
ALC	1.00							
Lecture	-0.38****	1.00						
Group Activity	0.14	-0.65****	1.00					
Discussion	0.85****	-0.06	0.07	1.00				
Podium	-0.61****	0.63****	-0.36****	-0.16*	1.00			
Consulting	0.37****	-0.52****	0.77****	0.18**	-0.35****	1.00		
Not at Podium	0.82****	-0.31****	0.45****	0.26***	-0.58****	0.33****	1.00	
Not Consulting	0.20*	0.18**	-0.11	0.02	0.26***	-0.40****	0.47****	1.00

NOTE: Cell entries are correlation coefficients (*rho*).
*$p < .05$; **$p < .01$; ***$p < .001$; ****$p < .0001$

Table 2. Pairwise Tetrachoric Correlations: Room Type, Activities, and Instructor Behavior.

The direction and strength of the correlations of behavioral and activity variables with room type reflects the patterns observed in the previous analysis of the differences by formal space type: ALCs are associated with discussion, consulting, moving around the room, and not consulting, the traditional classroom is associated with lecturing at or near the podium, and group activities are not correlated with space. Additionally, the remaining correlations make intuitive sense. For example, lecturing is inversely correlated with group activities, consulting, and moving about the room and positively correlated with being near the podium and not consulting with students. Similarly, the presence of group activities affords the instructor the opportunity to move about the room and to consult privately with an individual student or small groups of students. It also is not surprising that consulting and not consulting with students and being at the podium and not at the podium are inversely related. Finally, the lack of correlation between group activity and room type reflects the lack of significant difference in-group activities observed previously.

Given the strength and direction with which these variables related to the type of formal learning space and to one another and the time series nature of our observational data, it is possible to model causally the impact of these spaces on what takes place in the classroom. We can isolate the relative impact of each room by breaking out the observational data by section and use the classroom activity variables and instructor behavior variables while controlling for unmeasured constants to predict students' high levels of on-task behavior. We do this by employing a fixed effects logistic regression model of the following form:

$$\log(p_{it}/(1-p_{it})) = \mu_t + \beta_1 X1_{it} + \ldots + \beta_n Xn_{it} + \gamma Z_i + \alpha_i,$$

where

$i = 1, 2, \ldots, n$ and $t = 1, 2, \ldots, T$.

In this model, pit is the probability that the dependent variable – high levels of on-task student behavior – is equal to 1 for observation i at time t. Here μ is a time-variant intercept, $X1$ through Xn are the time-variant predictors (or independent variables), Z_i is the time-invariant predictor, and α_i is the combined effect of all unobserved variables that are constant over time. Additionally, our β_1 through β_n and γ are variable specific coefficients. With the introduction of a temporal lag of one period (t – 1), we algebraically reduce the equation to the following:

$$\log(p_{it}/(1-p_{it})) = (\mu_2 - \mu_1) + \beta_1(X1_{i2} - X1_{i1}) + \ldots + \beta(Xn_{i2} - Xn_{i1})$$

Since Zi and αi are time invariant variables, or constants, they are differenced out of the reduced form of the equation (Allison, 2009). In its complete form, our model for each formal classroom space is

$$\log(\Pr(\text{HIGH ON-TASK})) = \Delta\mu + \beta_1\Delta(\text{LECTURE}) + \beta_2\Delta(\text{GROUP ACTIVITY}) + \beta_3\Delta(\text{DISCUSSION}) + \beta_4\Delta(\text{PODIUM}) + \beta_5\Delta(\text{CONSULTING}) + \beta_6\Delta(\text{NOT AT PODIUM}) + \beta_7\Delta(\text{NOT CONSULTING}).$$

Thus, our model posits that the probability of high-levels of on-task student behavior in any given time t is dependent upon the values of the independent variables in the previous observational interval. This temporal component and controls for unobserved constants inherent to the fixed effects model coupled with the quasi-experimental design of the study affords us the opportunity for us to make causal claims about the impact of formal learning spaces.

Table 3 presents the results of our two fixed effects logistic regression models. The first model, which employs observational data from the section of the course housed in the traditional classroom, is statistically significant ($\chi2$ = 14.47; $p < .05$), suggesting that the constellation of classroom activities and instructor behavior explain well high levels of on-task student behavior in that section. However, the only variable that predicts significantly those high levels of on-task behavior in the traditional classroom is the traditional pedagogy of lecture (*OR* = 10.516; $p < .01$).

Table 3. Fixed Effects Logistic Regression Models: Instructor's Behavior and Classroom Activities' Impact on On-Task Behavior, by Section

	Model 1: Traditional Classroom	Model 2: Active Learning Classroom (ALC)
Lecture	10.516** (8.465)	1.681 (0.739)
Group activity	1.186 (1.203)	4.319** (1.924)
Discussion	-----	2.274* (0.936)
Podium	6.180 (9.760)	0.438 (0.211)
Consulting	10.200 (17.650)	0.698 (0.340)
Not at Podium	0.651 (0.597)	0.538 (0.339)
Not Consulting	0.0000 (0.001)	1.304 (0.767)
N	108	192
Chi-squared	14.47*	20.21**
Log likelihood	-18.379	-71.773

NOTE: Cell entries are odds ratios and standard errors (in parentheses).
*p < .05; **p < .01

Table 3. Fixed Effects Logistic Regression Space and Consequences.

Using a Yule's *Q* transformation ($Q = (O_{xy} - 1)/(O_{xy} + 1)$ of the reported odds ratio for interpretation purposes, we can say that when lecture activities transpire in any given observational interval in the traditional classroom, the likelihood of students exhibiting high levels of on-task behavior in the next observational interval is 82.63%. None of the other independent variables proved to be significant predictors of the dependent variable. And, class discussion is actually dropped from the model entirely due to a lack of variation given its highly infrequent appearance in the traditional classroom section of the course.

The second model, for which only data from the ALC section of the course was used, is also statistically significant ($\chi2$ = 20.21; $p < .01$) again suggesting that instructor behavior and classroom in-group activities directly affect student behavior. In the ALC, however, two variables that are associated with more active learning techniques predict significantly high levels of on-task student behavior: group activities (*OR* = 4.319; $p < .01$) and classroom discussion (*OR* = 2.274; $p < .05$). Holding all other factors constant, the probability of students engaging in on-task behaviors in a given interval is 62.40% if group activities are present in the immediately preceding interval while classroom discussion leads to high levels of on-task behavior in subsequent intervals approximately 39% of the time. None of the other independent variables predict significantly students being on-task at high rates. In fact, lecture becomes so insignificant that the probability of it prompting on-task behavior is only 25.40%, a drop of 57.23% from what it accomplishes in the traditional classroom.

Conclusion

The preceding observational analysis has contributed a significantly improved understanding of how formal classroom space shapes the behavior of instructors and students who work within them. In general terms, we have provided empirical evidence of a causal relationship that can be stated best in syllogistic terms: 1) space shapes instructor behavior and classroom activities; 2) instructor behavior and classroom activities shape on-task student behavior; therefore, 3) space shapes on-task student behavior. Specifically, different classroom types are conducive to different outcomes: traditional classrooms encourage lecture at the expense of active learning techniques while ALCs marginalize the effectiveness of lecture while punctuating the importance of active learning approaches to instruction, but both are effective at producing high levels of on-task student behavior. This suggests that different spaces are better suited for different types of activities, but can still achieve similar results. Furthermore, the evidence that active learning techniques do not work well in a lecture classroom and lecture does not work in an ALC suggests that instructors should consider adjusting their pedagogy to fit the space in which their course is held.

Two important caveats need to be addressed, however. First, while our results are robust due to the experimental design and analytical methods employed, the evidence presented here is based on a single course taught by the same instructor in one semester. To strengthen the generalizability of these results, additional courses and instructors have been recruited into the learning spaces research project at the University of Minnesota. And, while there is little reason to doubt that space has a causal impact on instructor behavior, classroom activities, and the levels at which students are on-task, the strength and direction of the relationships between the variables in this study might very well vary based on the characteristics of individual instructors. Indeed, preliminary analysis of a recently completed class observation sequences suggests this is the case. Second, the validity, but not the reliability, of the measure of on-task behavior is subject to scrutiny given that the operational measures being used are normatively prescribed (e.g. observed on-task behavior is indicated by students doing what they ought to be doing). In order to correct for this error, the research team responsible for this project is revising the entire class observation protocol prior to the next iteration of its deployment.

When coupled with previous research showing accelerated learning gains in the ALC environment, the reasonable conclusion is that active learning techniques used in spaces similar to the University of Minnesota's ALCs are superior to lecture-based instruction in traditional classrooms. Given that we know that active learning techniques are highly effective (Prince, 2004), the next stage of research should focus on what the value-added gains of using an active learning pedagogy in an ALC are relative to using those techniques in a traditional classroom setting.

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